International Journal for Modern Trends in Science and Technology
ISSN: 2455-3778 |Volume No: 02 | Issue No: 01 | January 2016

SVPWM Buck-Boost VSI

Kun Yang

Department of Electrical Engineering, Tsinghua University, China

Article History

Received on:	15-01-2016
Accepted on:	21-01-2016
Published on:	23-01-2016

Keyword

Boost inverter
total harmonic distortion,
Switching Losses,
Active power,
Reactive power ,
Voltage Source Inverter
Current Source Inverter

ABSTRACT

This paper presents a MATLAB based simulation results of a scheme with hysteresis current control strategy is preferred for a buck–boost voltage/ current source inverter modelled and simulated in MATLAB 2009a GUI environment using Simulink and Sim Power System set tool boxes by using ode23tb solver. In recent years, research in hybrid electric vehicle (HEV) development has been focused on various aspect of design, such as component architecture, engine efficiency, reduced fuel emissions, material for lighter components, power electronics, efficient motors and high power density batteries. A DC–DC converter with a high step-up voltage gain is used for many applications, such as high-intensity discharge lamp ballasts for battery backup systems for continuation of power to the drive by utilizing the VSI or CSI topologies . The dynamic analysis of proposed concept is implemented by using Matlab/Simulink Software Package and simulations results are presented, achieve high efficiency, high power density, high temperature, and low cost.

I. INTRODUCTION

Advancement in the research of Power electronic inverters is still increasing with the rapid demands in electrical systems. In the case of grid-connected systems using renewable energy sources, the total active power can be fed to the grid. For standalone systems supplying local loads, if the extracted power is more than the local loads (and losses), the excess power from the wind turbine is required to be diverted to a dump load or stored in the battery bank. Moreover, when the extracted power is less than the consumer load, the deficit power needs to be supplied from a storage element, e.g., a battery bank [1]. In the case of stand-alone or autonomous systems, the issues of voltage and frequency control (VFC) are very important [2].

Hybrid Electric Vehicle (HEV) is an emerging technology in the modern world because of the fact that it mitigates environmental pollutions and at the same time increases fuel efficiency of the vehicles. Voltage source inverter controls electric drive of HEV of high power and enhances its performance which is the reflection of the fact that it can generate sinusoidal voltages with only fundamental switching frequency and have almost no electromagnetic interference. This paper describes precisely various modulation techniques of HEVs and presents transformer less converter for high voltage and high current HEV in [1]. The inverter is IGBT based and it is fired in a sequence. It is natural fit for HEV as it uses separate level of dc sources which are in form of batteries or fuel cells. Compared to conventional vehicles, hybrid electric vehicles (HEVs) are more fuel efficient due to the optimization of the engine operation and recovery of kinetic energy during braking. With the plug-in option (PHEV), the vehicle can be operated on electric-only modes for a driving range of up to 30–60 km. The PHEVs are charged overnight from the electric power grid where energy can be generated from renewable sources such as wind and solar energy.

Varies types of modulation method have been proposed previously such as optimized pulse width- modulation improved, Space-Vector-PWM control for different optimization targets and applications and discontinuous PWM (DPWM). Different switching sequence arrangement can also affect the harmonics, power loss and voltage/current ripples. DPWM has been widely used to reduce the switching frequency, by selecting only one zero vector in one sector. It results in 50% switching frequency reduction. However, if an equal output THD is required, DPWM cannot reduce switching loss than SPWM. Moreover, it will worsen the device heat transfer because the temperature variation. A double 120 flattop modulation method has been used to reduce the period of PWM switching to only 1/3 of the whole fundamental period. However, these papers didn’t compare the spectrum of this method with others, which is not fair. In addition, the method is only specified to a fixed topology, which cannot be applied widely [6],[7].

Currently two existing inverter topologies are used for hybrid electric vehicles (HEVs) and electric vehicles (EVs): the conventional three-phase inverter with a high voltage battery and a three-phase pulse width modulation (PWM) inverter with a dc/dc boost front end. The conventional PWM inverter imposes high stress on switching devices and motor thus limits the motor’s constant power speed range (CPSR), which can be alleviated through the dc–dc boosted PWM inverter.

Fig. 1 shows a typical configuration of the series plug-in electric vehicle (PHEV). The inverter is required to inject low harmonic current to the motor, in order to reduce the winding loss and core loss. For this purpose, the switching frequency of the inverter is designed within a high range from 15 to 20 kHz, resulting in the switching loss increase in switching device and also the core loss increase in the motor stator. To solve this problem, various soft-switching methods have been proposed [1]–[3]. Active switching rectifier or a diode rectifier with small DC link capacitor has been proposed in [4], [5], [8]–[10]. Varies types of modulation method have been proposed previously such as optimized pulse-width-modulation [13], improved Space-Vector-PWM control for different optimization targets and applications [5]–[8], and discontinuous PWM (DPWM) [6]. Different switching sequence arrangement can also affect the harmonics, power loss and voltage/current ripples [2]. DPWM has been widely used to reduce the switching frequency, by selecting only one zero vector in one sector. It results in 50% switching frequency reduction. However, if an equal output THD is required, DPWM cannot reduce switching loss than SPWM. Moreover, it will worsen the device heat transfer because the temperature variation. A double 120 flattop modulation method has been proposed in [6] and [7] to reduce the period of PWM switching to only 1/3 of the whole fundamental period. However, these papers didn't compare the spectrum of this method with others, which is not fair. In addition, the method is only specified to a fixed topology, which cannot be applied widely.

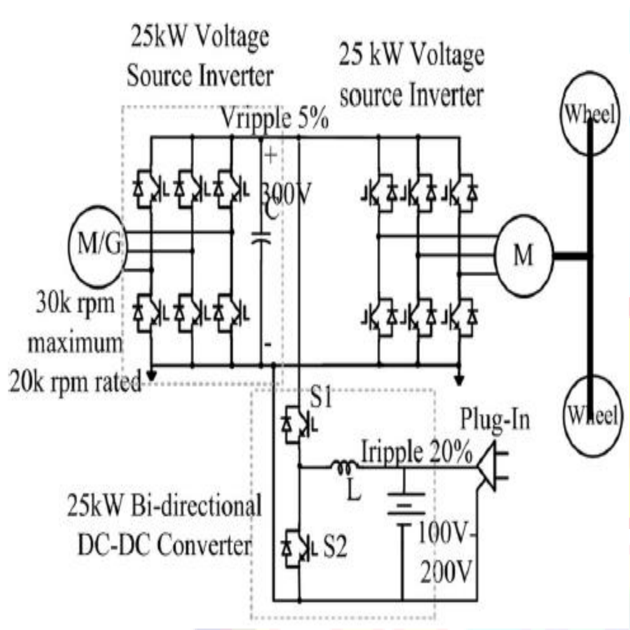

Fig.1. Typical configuration of a series PHEV.

This paper proposes a novel generalized space vector pulse width amplitude modulation (SVPWAM) method for the buck/boost voltage source inverter (VSI) and current source inverter (CSI). By eliminating the conventional zero vectors in the space vector modulation, two-third and one-third switching frequency reduction can be achieved in VSI and CSI, respectively. If a unity power factor is assumed, an 87% switching loss reduction can be implemented in VSI, and a 74% reduction can be implemented in CSI [8]-[10]. A 1-kW boost-converter inverter system has been developed and tested based on the SVPWAM method. Here authors prefer unit vector control strategy instead of SVPWM scheme because it is more complex compare to all other modulation schemes due to more number of vectors, so hard to design for more number of levels and prefer hysteresis based current control strategy have better features because controlled by unit vector control strategy, by using this technique get good THD response at output of the converter, may to reduce the load side filter value.

Space-vector pulse-with-modulation (SVPWM) is another technique of driving a voltage source three-phase H-bridge inverter, for generating voltage waveforms that are devoid of low frequency harmonic content. The principle of an SVPWAM control is to eliminate the zero vectors in each sector. The modulation principle of SVPWAM is shown in Fig.2. In each sector, only one phase leg is doing PWM switching; thus, the switching frequency is reduced by two-third. This imposes zero switching for one phase leg in the adjacent two sectors. For example, in sector VI and I, phase leg A has no switching at all. The dc-link voltage thus is directly generated from the output line-to line voltage [5].

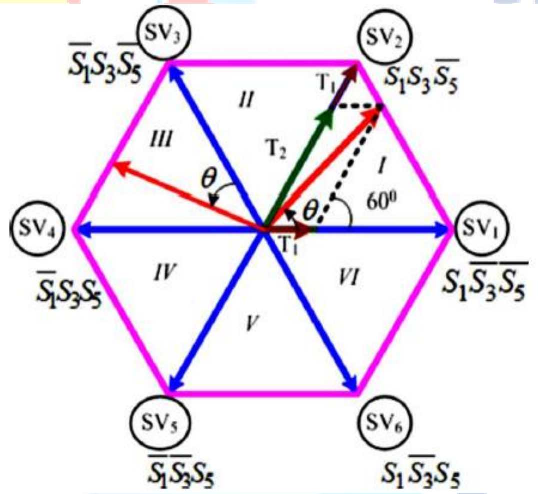

Fig.2. SVPWAM for VSI

II. SWITCHING LOSS REDUCTION FOR VSI TOPOLOGY

For unity power factor case, the inverter switching loss is reduced by 86% because the voltage phase for PWM switching is within [−60◦, 60◦], at which the current is in the zero-crossing region. In VSI, the device voltage stress is equal to dc-link voltage VDC, and the current stress is equal to output current ia . Thus the switching loss for each switch is

$$
\begin{aligned}
P_{\mathrm{SW\_I}} &= \frac{1}{2\pi}\left[\int_{-\pi/6}^{\pi/6} E_{\mathrm{SR}} \frac{|I_m \sin(\omega t)| \cdot V_{\mathrm{DC}}}{V_{\mathrm{ref}} I_{\mathrm{ref}}} \cdot f_{\mathrm{sw}}\, d\omega t \right.\\
&\quad \left. + \int_{5\pi/6}^{7\pi/6} E_{\mathrm{SR}} \frac{|I_m \sin(\omega t)| \cdot V_{\mathrm{DC}}}{V_{\mathrm{ref}} I_{\mathrm{ref}}} \cdot f_{\mathrm{sw}}\, d\omega t \right]\\
&= \frac{2-\sqrt{3}}{\pi} \cdot \frac{I_m V_{\mathrm{DC}}}{V_{\mathrm{ref}} I_{\mathrm{ref}}} E_{\mathrm{SR}} \cdot f_{\mathrm{sw}}, \qquad (2)
\end{aligned}
$$

Where *E*SR, *V*ref, *I*ref are the references

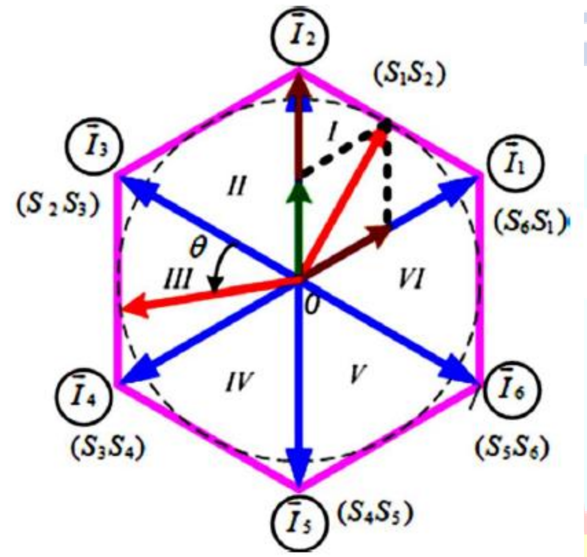

Fig. 3: Conventional CSI and its corresponding SVPWAM diagram.

In result, the switching loss of SVPWAM over SPWM is *f* = 13.4%. However, when the power factor decreases, the switching loss reduction amount decreases because the switching current increases. As indicated, the worst case happens when power factor is equal to zero, where the switching loss reduction still reaches 50% in [9]. In conclusion, SVPWAM can bring the switching loss down by 50–87%.[3]

III. UNIT VECTOR CONTROL STRATEGY

The control diagram for a three phase inverter is shown in Fig. 4. The regulation of dc-link voltage carries the information regarding the exchange of active power in between inverter. Thus the output of dc-link voltage regulator results in an active current (Im). The multiplication of active current component (Im). With unity grid voltage vector templates (Ua,Ub, and Uc) generates the reference voltages and currents . The grid synchronizing angle (θ) obtained from phase locked loop (PLL) is used to generate unity vector template as [9]–[10]

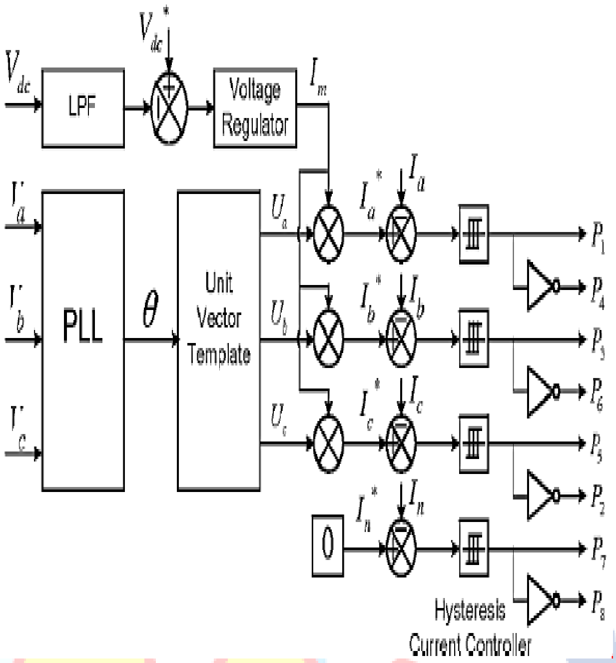

Fig.4: Block diagram representation of grid interfacing inverter control.

The switching pattern of each IGBT inside inverter can be formulated on the basis of error between actual and reference current of inverter, which can be explained as: If IInva < (I*Inva-hb), then upper switch S1will be OFF (P1 =0) and lower switch S4 will be ON (P4=1) in the phase “a” leg of inverter. If IInva > (I*Inva-hb), then upper switch S1 will be ON (P1 =1) and lower switch S4 will be OFF (P4=0) in the phase “a” leg of inverter Where hb is the width of hysteresis band. On the same principle, the switching pulses for the other remaining three legs can be derived [4].

IV. MATLAB SIMULATION MODEL AND RESULTS

Here simulation is carried out in several cases, in that here simulation is carried out in several configurations. Fig.5 shows the matlab based simulation diagram of proposed system. Fig.6. shows the MATLAB based simulation graph of control signal of proposed system. Fig.7. shows the output responses of proposed inverter. Fig.8. shows the output responses of motor drive. Fig.9 shows the gate triggering pulses

From simulation results it is seen the proposed topology of buck-boost single phase voltage inverter works exceptionally well producing an *ac* sine wave output depending upon the reference sine wave amplitude given to control circuit.

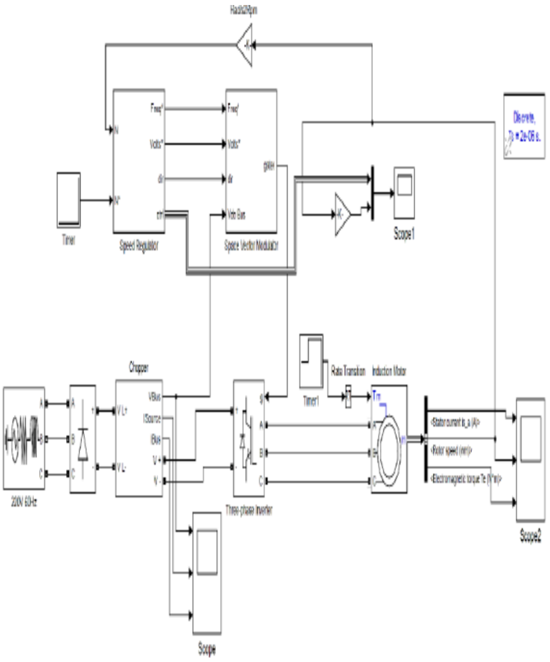

Fig.5.MATLAB based masked diagram of proposed system

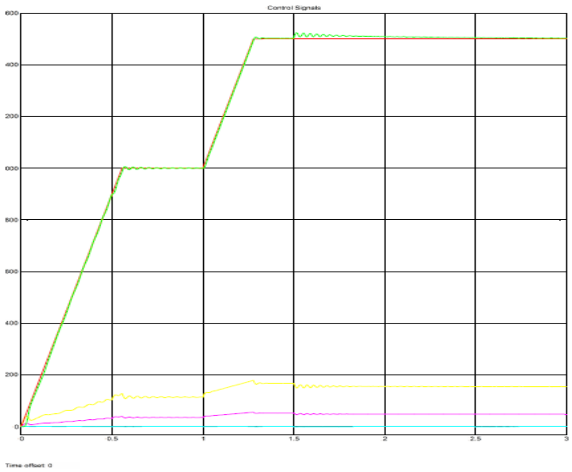

Fig.6.MATLAB based simulation graph of control signal of proposed system.

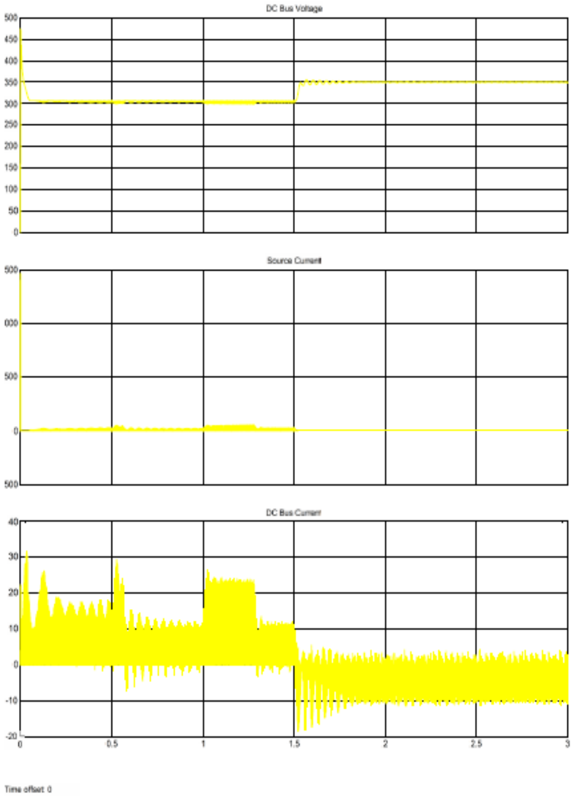

Fig.7. Output responses of proposed inverter

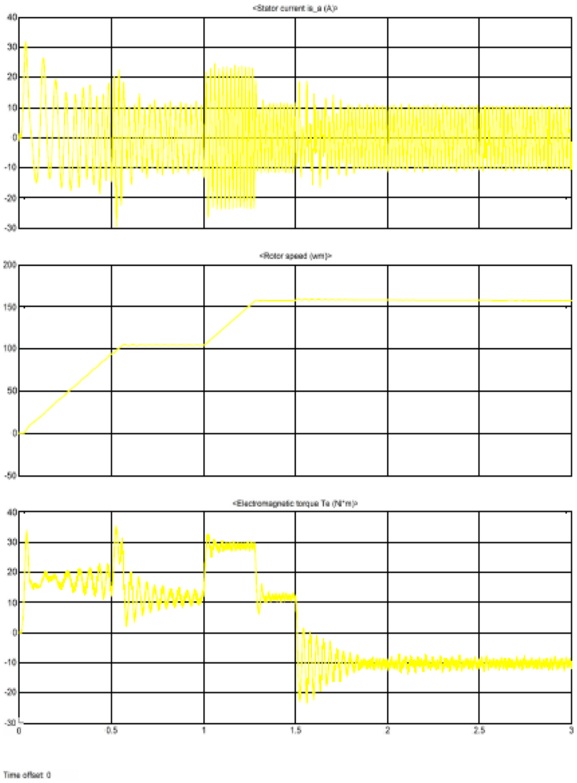

Fig.8.Output responses of motor drive

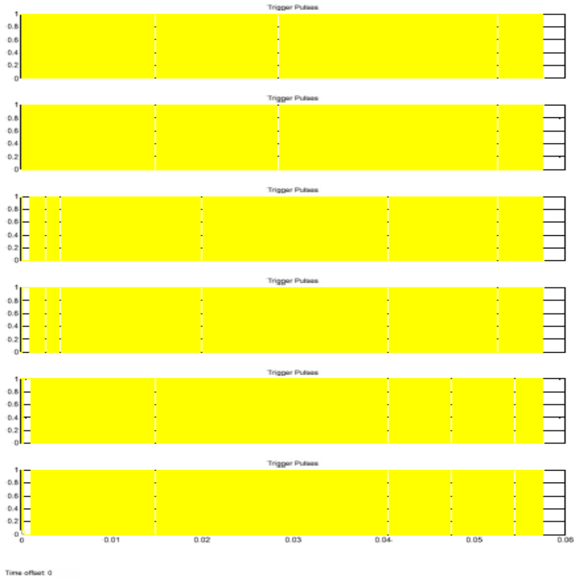

Fig.9. Gate triggering pulses

CONCLUSION

The proposed inverter is applicable as a utility interactive inverter for distributed generating systems and harmonic elimination applications. The proposed inverter uses six switches. The low switching frequency of the output H-bridge reduces inverter switching losses and costs, compared to six and eight switch-based techniques. Experimental results that confirm the feasibility of proposed boost inverter. The effectiveness of the proposed method in reduction of power losses has been validated by the experimental results that were obtained from the MATLAB/Simulink based circiut.

REFERENCES

[1] R. Gonzalez, E. Gubia, J. Lopez, and L.Marroyo "Transformerless single phase multilevel-based photovoltaic inverter," *IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2694–2702, Jul. 2008.*

[2] Ahmed Mohamed Salamah, Stephen J. Finney "Single- Phase Voltage Source Inverter with a Bidirectional Buck– Boost Stage for Harmonic Injection and Distributed Generation" *IEEE transactions on power electronics, vol. 24, no. 2, pp 376- 387, February 2009.*

[3] L. G. Franquelo, K. Gopakumar, S. Kouro, J. I. Leon, M. Malinowski, M. A. Pérez, J. Pou and B.Wu, J. Rodríguez, "Recent advances and industrial applications of multilevel converters" IEEE Trans. Ind. Electron ,2010, vol. 57, no. 8.

[4] Roman, I.T. "A single-phase current-source inverter with active power filter for grid-tied PV systems", *3rd IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Aalborg, pp. 349-356, June 2012.*

[5] Yan Zhang "Comparison of traditional two-stage buck- boost voltage source inverter and diode-assisted buck-boost boost voltage source inverter and diode-assisted buck-boost voltage source inverter" Twenty-*Seventh Annual IEEE trans on Applied Power Electronics Conference and Exposition (APEC), Orlando, FL, pp 141-148, Feb 2012.*

[6] Samuel, P. "Grid Interface of Wind Power With Large Split-Winding Alternator Using Cascaded Multilevel Inverter" *IEEE Transactions on Energy Conversion, Volume: 26, Issue: 1, pp 299-309, March 2011*

[7] Jalbrzykowski, S, Citko, T. "Current-Fed Resonant Full- Bridge Boost DC/AC/DC Converter" *IEEE Transactions on Industrial Electronics, Volume: 55, Issue:3, pp 1198 – 1205, March 2008.*

[8] F. Z. Peng, "Z-source inverter," *IEEE Trans. Ind. Appl.*, vol. 39, no. 2, pp. 504–510, Mar./Apr. 2003

[9] K. Srinivasan and Dr.S.S.Dash,"Performance Analysis of a Reduced Switch Z-Source Inverter fed IM Drives",International Journal of Computer and Electrical Engineering, Vol. 2, No. 4, August, 2010 ,1793 - 8163.

[10] J. S. Kim and S. K. Sul, "New control scheme for ac-dc-ac converter without dc link electrolytic capacitor," in *Proc. 24th Annu. IEEE Power Electron. Spec. Conf., Jun. 1993, pp. 300–306.*

[11] K. Rigbers, S. Thomas, U. Boke, and R. W. De Doncker, "Behavior and loss modeling of a three-phase resonant pole inverter operating with 120°A double flattop modulation," in *Proc. 41st IAS Annu. Meeting IEEE Ind. Appl. Conf., Oct. 8–12, 2006, vol. 4, pp. 1694–1701.*